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A Landscape Ecological Management System for Sustainable Urban Development

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Abstract

This study conducted an empirical analysis to enhance landscape ecological performance in urban spaces using landscape ecology. To do so, concrete criteria and standards to analyze structural, functional and variational mechanisms of urban landscape ecology was developed. Combining the criteria, an integrated landscape ecology assessment model that can be applied to urban planning was established. Next, a GIS based Landscape Ecological Management System (LEMS) was created to realize an integrated assessment model. To verify the effectiveness of the model, a scenario analysis was conducted using a developed system on Byulne City in the Seoul Metropolitan Area. The results presented quantitative results and spatial solutions for each alternative. These results can be useful for urban planners and policy makers in their selection of desirable alternatives.

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Keywords: Landscape ecology; Landscape ecological management system; Sustainable development

1. Introduction

Studies on landscape ecology have focused on conceptual aspects, while empirical focus for spatial planning has been rarely conducted. This study developed the landscape ecological management system to harmonize conflicting problems in urban spaces. To achieve this, the landscape ecology assessment elements for urban spaces were identified by literature review and assessment methods were established. Next, a GIS based landscape ecological assessment management system was established. To verify the effectiveness of the system, a case study was conducted using the assessment model. The landscape ecological assessment model developed in this study can contribute toward the preparation of policies regarding environment-friendly planning for planning tools of scientific and systematic evaluation.

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2. Establishment of the landscape ecological management system

2.1. Assessment criteria and the integrated assessment model

Landscape ecology considers the structures on and the functions of the landscape, and is useful in resolving ecological problems [5]. In landscape ecology, the landscape component is divided into three elements; structure, function, and variation (figure 1). Many criteria were developed to assess landscape components. In this study, the landscape ecology assessment elements for urban spaces were identified by literature review.

The landscape structure can be explained by distributed information states that are related to landscape elements like spatial size, shape, number, type, direction, and organization of landscape elements. Area, perimeter, and shape index were adopted to assess landscape structure, because these are the most representative indices for analyzing landscape structure. Next, function assessment refers to evaluating the interaction of patches. To evaluate the functions, fragmentation and connectivity were selected in this study. Spatial auto-correlation analysis was adopted to assess fragmentation of patches caused by spatial distribution. The gravity model and least-cost path analysis were applied to assess connectivity. Using the gravity model theory, large areas and short distances were found to cause high connectivity, as opposed to small forest areas and long distances that caused low connectivity [3]. Meanwhile, least-cost path analysis is a networking methodology based on landscape permeability theory, and is an effective method for constructing ecological networks by considering landscape characteristics. Finally, biodiversity and NDVI (Normalized Difference Vegetation Index) were adopted to assess landscape variation. Landscape ecology performance can be assessed by a combination of structure, function, and variation. Combining these criteria, the integrated landscape ecology assessment model which can be applied to urban planning processes was established (Figure 2)

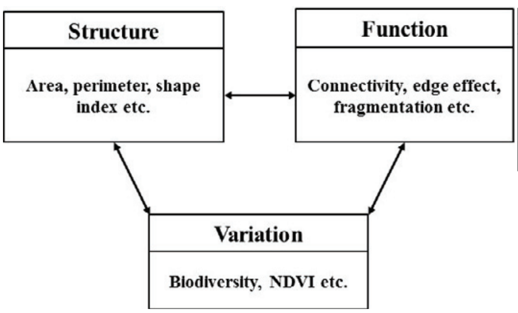


Fig. 1. Assessment criteria of landscape ecology [6]

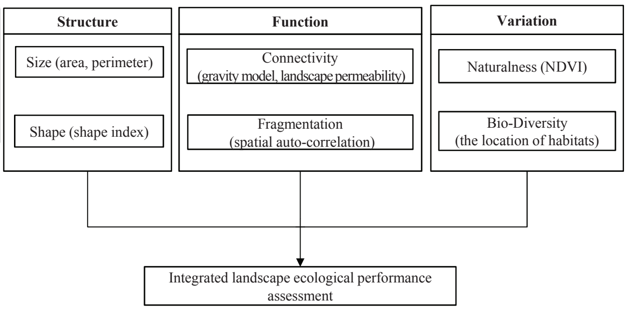
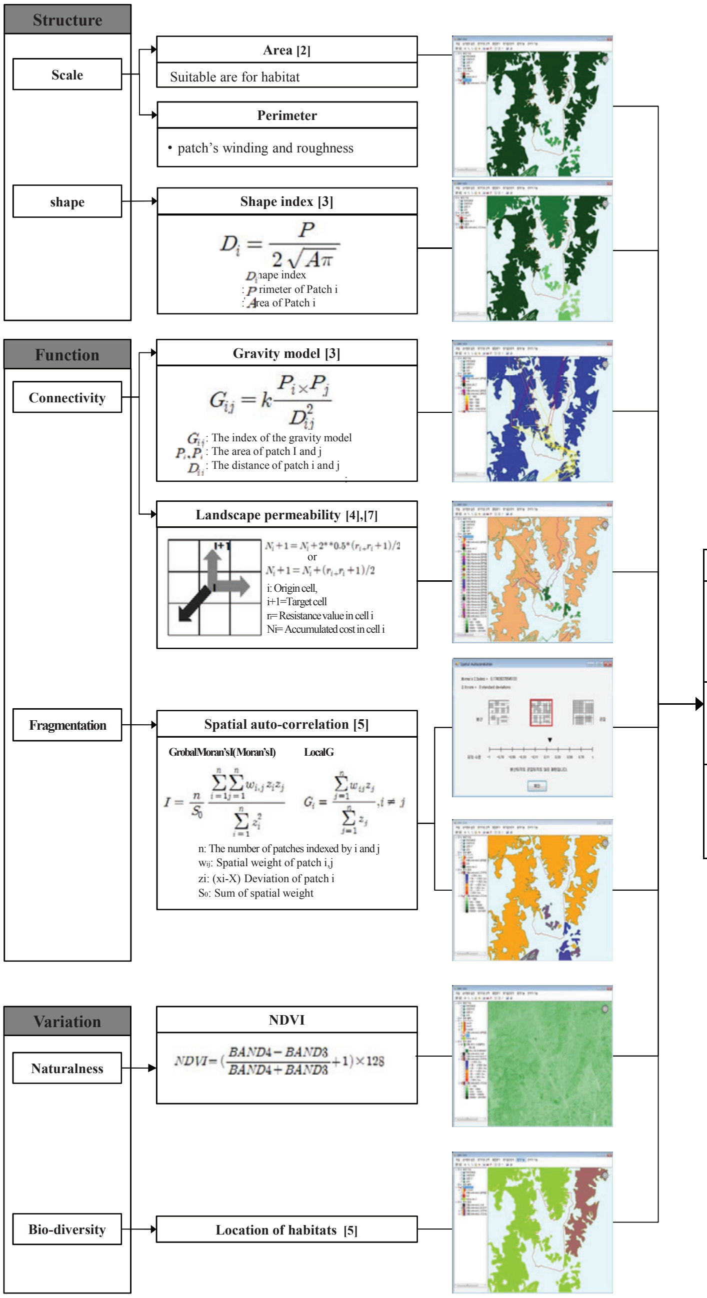


Fig. 2. Integrated landscape ecological assessment

2.2. The Landscape ecological management system

The Landscape ecological management system was developed using Visual Basic 6.0 and Intramap Object (Korea GIS engine). The system consists of basic GIS functions, landscape ecological assessment criteria, and integrated landscape ecological assessment. Figure 3 shows the integrated assessment model for the main function of the system.



Classification			Results
Structure	The number of patches		8
	Area	Total area (ha)	43.72
		Average area (ha)	5.46
	Average shape index		0.008
Fragmen -tation	Average distance (m)		2,445
	Area (Moran's I)		0.1 (Clustered)
	Shape Index (Moran' I)		-0.04 (Random)
Connecti vity	Gravity model	The uumber of networks	18
		Average gravity index	12,013
	Landscape permeability		22,996

Fig. 3. Integrated landscape ecological assessment

3. Case study

3.1. Study methods

The integrated assessment model was applied to a real development project. Three scenarios (before development, development plan, and improved development plan) were prepared to analyze the development impact (Table 1). Next integrated landscape ecological performance on each scenario was evaluated using LEMS.

Table 1. Assessment scenario

Classification	Contents
Scenario 1	▪ Before development: Connecting forest using connectivity results (more than high rank 30%) ▪ Forest placement on major connected area ▪ Total forest area should not exceed no more than 30% of total area
Scenario 2	▪ Development plan (Total forest area ratio: 28.8%) ▪ The forest area less than 1ha were not considered because they do not have ecological function
Scenario 3	▪ Improved development plan: Additional corridor placement using connectivity analysis ▪ Total forest area should not exceed no more than 30% of total area

3.2. The study area

The study area is the 'Byulne' urban development project of the capital region, i.e. the Seoul Metropolitan Area. This area was removed from the green belt area by national policies and subsequently, large urban development projects were planned. The development area is about 5km^2 and 76,000 people will inhabit this area (Figure 4).

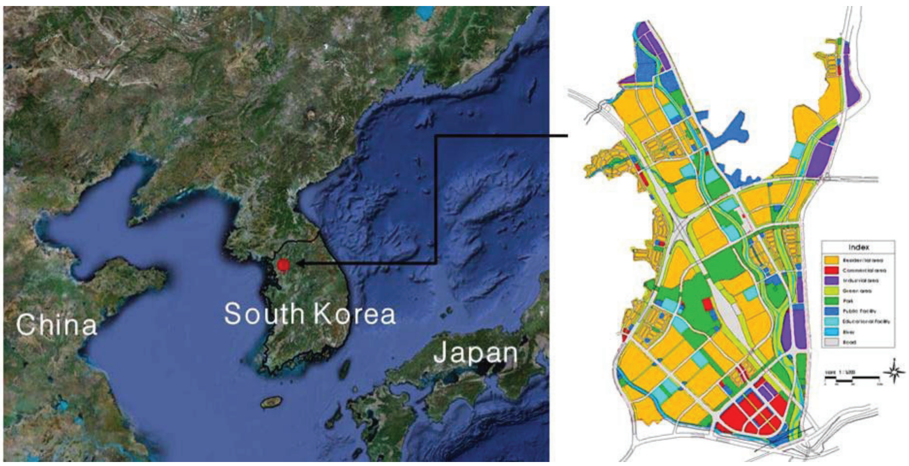


Fig. 4. The study area

3.3. Results

The number of patches increased from 8 to 196 after urban development. As a result, the total patch area also increased form 43.72ha to 97.96ha. However, the average area has decreased about 4.8ha. This result was caused by variously planned patch types like parks, corridors, and buffers. The patch fragmentation patterns based on area were determined as cold spots (Z<2.58) in all scenarios. As regional Moran's I changed from 0.1 to 0.03, the fragmentation increased a little after development. This means fragmentation of small patches occurred in the study area. These results were caused by the location of large patches near the study area. The large patch of the northern area changed into a hot spot as the number of small patches sharply increased after development. The patch fragmentation patterns based on shape index was determined randomly in all cases, and some clustering was found to have occurred after development.

Meanwhile, the average distance of patches decreased from 2,445m to 1,569m. Consequently, the fragmentation condition improved after urban development, considering increases of the number and size of the patches. The connectivity assessment results based on the gravity model showed the number of patches networks increased about fourfold. However, a sixfold decrease of the gravity index occurred after development. This result was caused by an individually insufficient patch area securement compared with the number of patch increase. This also means that a large patch area could not be secured due to a road network plan. In the meantime, the connectivity assessment result based on landscape permeability showed the friction value increased by eighteenfold. This was the result of landcover, like flora (which is suitable for animal migration) being changed into urban areas after development.

Urban development has resulted in positive effects like patch number increase, total area increase, and fragmentation improvement in the study area. However, negative impacts such as average shape index increase and connectivity decline also occurred. Negative impacts were caused by landcover variations and road network construction. These negative impacts disturbed sufficient patch area securement to meet landscape ecological functions. Therefore, the fragment areas are connected through scenario 3. As a result, patch area and connectivity were enhanced somewhat by extra corridors (Table 2).

Table 2. Assessment result

Classification			Before development	Development plan	Improved development plan
Structure	The number of patches		8	135	66
	Area	Total area (ha)	43.72	97.96	98.76
		Average area (ha)	5.46	0.62	0.61
	Average shape index		0.008	0.032	0.032
Fragmentation	Average distance (m)		2,445	1,569	1,369
	Area (Moran's I)		0.1 (Clustered)	0.03 (Clustered)	0.03(Clustered)
	Shape index (Moran' I)		-0.04 (Random)	-0.01 (Random)	-0.01(Random)
Connectivity	Gravity model	The number of networks	18	70	79
		Average gravity index	12,013	2,227	2,117
	Landscape permeability		22,996	424,537	423,386

4. Conclusion

The study's usefulness is as follows: First, a practical integrated landscape ecology assessment model for mitigating ecological problems was established. Second, effective analysis for urban planning and polices were made possible using the developed assessment system. Finally, concrete and practical management policies were suggested to minimize landscape ecology damage. Therefore, through the presentation of scientific and concrete results, the study results can be adopted to urban forest planning, environment planning, and so on. The integrated assessment model can also contribute toward the creation of spatial alternatives to improve landscape ecological performance. Moreover, the landscape ecological management system developed in this study can be a useful tool for academia in terms of the implementation of further related studies, and for private enterprises in their implementation of environmental impact assessment (EIA).

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